This is a digital copy of a book that was preserved for generations on library shelves before it was carefully scanned by Google as part of a project to make the world's books discoverable online.

It has survived long enough for the copyright to expire and the book to enter the public domain. A public domain book is one that was never subject to copyright or whose legal copyright term has expired. Whether a book is in the public domain may vary country to country. Public domain books are our gateways to the past, representing a wealth of history, culture and knowledge that's often difficult to discover.

Marks, notations and other marginalia present in the original volume will appear in this file - a reminder of this book's long journey from the publisher to a library and finally to you.

Usage guidelines

Google is proud to partner with libraries to digitize public domain materials and make them widely accessible. Public domain books belong to the public and we are merely their custodians. Nevertheless, this work is expensive, so in order to keep providing this resource, we have taken steps to prevent abuse by commercial parties, including placing technical restrictions on automated querying.

We also ask that you:

+ *Make non-commercial use of the files* We designed Google Book Search for use by individuals, and we request that you use these files for personal, non-commercial purposes.

+ *Refrain from automated querying* Do not send automated queries of any sort to Google's system: If you are conducting research on machine translation, optical character recognition or other areas where access to a large amount of text is helpful, please contact us. We encourage the use of public domain materials for these purposes and may be able to help.

+ *Maintain attribution* The Google "watermark" you see on each file is essential for informing people about this project and helping them find additional materials through Google Book Search. Please do not remove it.

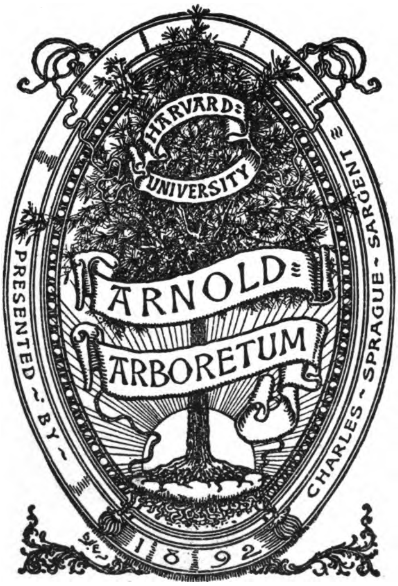
+ *Keep it legal* Whatever your use, remember that you are responsible for ensuring that what you are doing is legal. Do not assume that just because we believe a book is in the public domain for users in the United States, that the work is also in the public domain for users in other countries. Whether a book is still in copyright varies from country to country, and we can't offer guidance on whether any specific use of any specific book is allowed. Please do not assume that a book's appearance in Google Book Search means it can be used in any manner anywhere in the world. Copyright infringement liability can be quite severe.

About Google Book Search

Google's mission is to organize the world's information and to make it universally accessible and useful. Google Book Search helps readers discover the world's books while helping authors and publishers reach new audiences. You can search through the full text of this book on the web at `http://books.google.com/`

Tl
Si4

JP



~~DEPOSITED AT THE
HARVARD FOREST
1943~~

RETURNED TO J. P.
MARCH, 1967

No. 10, 1899.

CAPE OF GOOD HOPE.

Department of Agriculture.

ELEMENTARY PRINCIPLES OF SYLVICULTURE OR WOODCRAFT.

T. R. Sim

Reprinted from the Agricultural Journals of March 30th, 1899, and April 13th, 1899.

CAPE TOWN:
TOWNSHEND, TAYLOR AND SNASHALL, PRINTERS.

34167
Oct 23, 1922

ELEMENTARY PRINCIPLES OF SYLVICULTURE OR WOODCRAFT.

The following paper on the above topic was read at the Grahamstown Exhibition by Mr. Thos. R. Sim, F.L.S., District Forest Officer, King William's Town :—

Increased sylviculture is one of the pressing needs of this Colony. For centuries sylviculture has been recognised as an art, requiring in its successful pursuit the long-continued observation, and subsequent comparison of facts, bearing on the subject, and borne out in practice, and the deduction from these of the bearing which scientific principles have on the practical operations of, and the theories underlying, success in it.

I do not propose to-day to go into the reasons why sylviculture should be extended, nor to give details of practice in connection with it, but rather to confine my remarks entirely to the principles above mentioned.

The whole subject is regulated in the first case by the actual life processes of plants in general, and more particularly of timber trees, and since it is only by taking full advantage of these, and giving opportunity for special development in any desired direction, that sylviculture can be successful, a clear understanding of these is a necessary preliminary to further study; for trees, like all other organic beings, are more or less subject to the action of external influences, which produce by gradual evolution special forms particularly adapted for special conditions.

Absorption and Exhalation.—Plants require and utilise food which is absorbed partly from the soil and partly from the atmosphere, and always in a liquid or gaseous condition. Analyses show that the minute individual cells of which all plants are built up, have thin enclosing membranes (known as cell walls) which in their chemical composition are a combination of oxygen, hydrogen and carbon. In a living plant these cells contain the peculiar protoplasmic sap which is proof of, and essential to, life, and which contains nitrogen besides the above-mentioned three elements.

Traces of various minerals are also present in most plants in quantities varying in accordance with the kind of plant and the soil in which its growth has been made. These mineral substances are received into the plant from the soil, through the roots, in solution in the water which has picked them up while filtering through the soil. As the roots have entire membranes through which this water has to pass into the plant, the minerals must be in the exceedingly fine form produced by actual chemical combination with the water, and not simply floating in it. The sap then passes up through the stem into the leaves, which act as lungs, as the expanded surface exposes it to light, and to contact with the atmosphere. A leaf itself is not a solid body, but it is composed of innumerable cells, contained within a covering epidermis, and usually having numerous openings on the under surface (known as stomata, or breathing pores) leading into irregular interstices between the cells inside the leaf. Through these stomata atmospheric air enters the interstices, and comes in contact with the sap contained in the cells, the walls of which throughout the plant are not so impervious but that transmission of liquids or gases can take place. Chemical changes then take place, by which the surplus of oxygen and hydrogen from the mixed sap and atmospheric air is set free and escapes again, while the carbon and sufficient oxygen and hydrogen to form the proportion required for cellulose (or cell-wall) is retained, as also nitrogen for the protoplasm (or living sap).

This process, which may be described as breathing going on continually, but more especially under sunlight, liberates an enormous quantity of oxygen and hydrogen (or water) which to allow the process to continue has to be replaced from the cells below. These again draw on the roots, and the roots draw on the surrounding soil, so that a constant pumping action is produced, which proceeds the more rapidly in accordance with the increase of exhalation, which again is greatest under strong light (if the number of stomata be equal); hence plants in such a warm and clear atmosphere as that of this Colony can absorb and exhale a much larger amount of moisture than they do in a climate like North Europe; and as all this additional exhalation carries along with it the fixture of a larger quantity of organic elements in the plant (as well as the inorganic) it follows that growth and wood formation is much more rapid, and that this increases in proportion to the amount of foliage exposed to sunlight.

In all ordinary timber trees the sap after undergoing the processes above-mentioned in the leaf, whereby it is reduced in quantity, but increased in quality, passes back into the stem, and finds its way partly into a layer of soft young tissues known as the cambium layer, placed between the timber and the bark, and partly into the young growing buds. These are the two centres of active growth, that in the bud being mostly in the nature of expansion forward, forming new stems by the addition of length, while that in the cambium layer is mostly in the nature of expansion outward, giving increased timber by the addition from the inner surface of the layer of a fresh ring of timber surrounding those formed in previous years, and also giving from its outer surface a fresh ring of bark inside those of previous years. The actual formation of timber in each case is by a process of sub-division of the cambium cells, and the subsequent increase to normal size of the small cells formed by this sub-division. All this increased amount of cell-wall utilizes the additional cellulose supplied by the leaves, hence if that supply be large the increase in timber goes on rapidly, and *vice versâ*.

It will be seen from the above that though a sufficient supply of water at the roots is necessary to allow the pumping action to continue, and though without that supply the leaves wilt, and the branches become dried out, still it is more particularly upon the supply of carbon and nitrogen that the plant is dependent for the formation of new tissues.

Carbon is absorbed by the plant in the form of carbon dioxide (CO_2) mostly from the atmosphere through the stomata, and the formation of elaborated sap and cellulose is accomplished by the decomposition of this gas under the influence of light, in the green parts of the plant; its oxygen is given off, and its carbon unites with the sap in the cells, forming what are known as ternary compounds (carbon, oxygen, and hydrogen), which include starch, sugar, elaborated sap, and cellulose, all capable of, and subject to, transformation from the one to the other by slight natural changes.

Nitrogen is abundant in the atmosphere, but in a form which is not acceptable to plants, and it is only when in combination with other elements (as in ammonia or nitrates) that the plant receives it, and then mostly through the roots. The nitrification of the soil is also accomplished by bacterial agency under a process known as "Symbiosis," in which certain leguminous plants play such an important part that we may infer that Acacias, Robinia, Gleditschia, and other allied trees assist to enrich the soil in this manner more than the other non-leguminous trees.

Plants possess a remarkable power of selection with regard to what elements are absorbed by the roots. And it does not follow because a tree is growing in a soil composed largely of silica, that that tree will absorb a large quantity or any quantity of silica, and so also with regard to the various other elements. But with the elements which are essential to plant life, more especially nitrogen, and the minerals, the better the supply in the soil is, the more likely are these to get into the condition in which they can be absorbed; while if any of them are altogether awanting, or present in too limited a quantity, or in an insoluble form, then plant life languishes or dies out. From this circumstance arises in agriculture the necessity for supplying in the form of manure whatever element is wanting in certain soils, or whatever element by continued absorption by vegetable crops becomes scarce. But different plants have different requirements. Thus cereal crops select silica, while most other green vegetables prefer potash and nitrogen, the proportionate quantity of each substance accepted and retained being shown by chemical analysis of the entire plant.

From this circumstance arises the necessity when tree-planting of selecting kinds of trees exactly suited to the composition of the soil, since the nature of the latter cannot be materially changed afterwards. It occasionally happens however that all the necessary elements are present in the soil, but that they are in form or combination insoluble in water, and so cannot be utilised. To remedy this the simplest and most natural cure is exposure to atmospheric action, which in its disintegrating and weathering action gradually reduces most substances to a soluble condition, and at the same time imparts from the atmosphere itself, or from what is floating in it, such necessary ingredients as will enter into combination with the substances already in the soil, and be thereby fixed in fit form for plant use. This accounts for the advantages of tillage, and explains how repeated ploughing and pulverising has a greater effect than can be ascribed to the mechanical operation alone. But to be successful this exposure to atmospheric action must be more than surface deep. Plant roots are in the soil, under the surface, and often at considerable depths, and very rapidly exhaust the supply of certain elements as far as in available form, unless these are constantly receiving additions from outside, or having the supply on hand transformed into a condition in which it can be utilised. Both these are accomplished by "aeration of the soil," which goes on in this way, viz :—During rain or irrigation the interstices between the particles of soil become filled up with water, and any air that may previously have filled up these interstices is thereby driven out. If the soil has good natural drainage, or is sufficiently drained artificially, this water drains off, and would leave the interstices empty were it not that the vacuum thereby produced acts as a suction pump, and draws the atmospheric air into every crevice, and thereby allows the chemical process known as "weathering" to proceed, and render soluble valuable plant food which previously was in an insoluble condition. The next rain again drives out this air, and on draining away draws in more, so the process proceeds as regularly as breathing in animals, and always with disintegrating, and consequently feeding effect. But if when water is supplied, instead of draining away, it remains stagnant, these chemical changes cease, soluble ingredients of plant food are apt to be floated out to the surface, and washed away, and other chemical changes take place, which have a poisonous effect, causing roots under continued saturation soon to become unhealthy and die.

During the interval between rains aeration continues in a different method, for as the weathering process fixes certain atmospheric elements, and liberates others, these latter again diffuse themselves into the atmosphere, and are replaced in the soil by fresh and more fully charged atmospheric air.

What I have said thus far applies equally to agricultural and sylvicultural crops, and underlies all successful cultural operations with regard to either, but now comes a distinction.

Humus.—Agricultural crops in this Colony are carried bodily off the ground, and usually sent to market and used in the towns, consequently the soil loses feeding value year by year to the extent of the crop carried off, minus what has been added or liberated by soil aeration, and what has been added as manure. But in the case of a timber crop little or nothing is carried off the ground until the end of the rotation, which may be 10, 20 or 100 years; even then the timber removed consists very largely of carbon, which is always easily replaced naturally by any succeeding crop; but during the course of the rotation an enormous amount of fallen leaves has gone to add to the fertility of the soil, which is thus both in mechanical condition, and in chemical composition, in much better form at the end of a timber rotation than at its commencement. This is easily seen on the bush-covered coast dunes, where a rich black soil a foot or more in depth, and composed entirely of vegetable humus, is sometimes to be found over-lying the pure sea sand in which the trees commenced to grow. The inverse process is seen where rich forest land is cleared of forest, and cultivated in cereals, until after 10 or 20 years it is "worked done." Not only does a timber crop accumulate humus, but it benefits by it meantime, and in more ways than one. The humus itself is a highly fertile soil, in which, without any other ingredients, tree life is strong and vigorous, for since its composition is highly organic, its decay not only yields valuable plant-feeding materials, but continues to receive and fix these from the atmosphere in fit form for use as required. But besides this, its mechanical condition, which is very open and porous, assists the complete aeration of its particles and interstices; it also assists drainage, and prevents saturation; it absorbs a much larger amount of rain without damage to plant life than most other soils, and it continues to absorb moisture without allowing almost any to run off during heavy rains, which, stored in this hygroscopic sponge, can percolate more slowly into the subsoil afterwards instead of going off in floodwaters, and cutting dongas which drain the country down to the rock surface. Humus also acts as a perfect mulch, preventing evaporation, and keeping the subsoil cool. It will be seen therefore that in such a country as this, and especially in the drier parts of it, having comparatively a low rainfall, a high temperature, long-continued seasons of drought, and in many places no rains except very heavy thunder-showers which are apt to run off, a heavy mulching with humus must be of enormous advantage to a timber crop, and every endeavour must be made to secure this at as early a stage of the crop as possible.

The amount of humus produced varies exceedingly with different kinds, but in a general way deciduous trees and pines produce much more than others, and as deciduous trees generally thrive best in bottom lands, where humus is less of an absolute necessity, and where also gums, wattles, and other kinds do well, pines remain the most satisfactory kinds for planting on high and dry ridges where the beneficial effect of humus is very evident, as also on all the dry and presently treeless slopes of the higher mountain ranges. On such ground, especially if the aspect happen to be a northern one, the formation of soil and the retention of moisture are of first importance, and can best be produced by having pines closely planted or sown, so that an abundance of fallen leaves may cover the ground at an early date. Close stocking also secures other advantages to which reference may now be made.

Canopy.—Direct sunlight upon the surface of the soil has a very drying effect anywhere, but more especially on such a hot northern exposure as has just been described, consequently any means by which this can be lessened is welcome. In sylviculture the effective means at hand is to so regulate the stock of trees as to secure, as soon as the trees begin to form branches, a complete canopy under these branches, which is thereafter maintained as long as the crop is on the ground. This canopy, which nature always endeavours to produce, can be secured to young crops either by stocking close enough to bring the trees into such contact as completely shadows the ground without the formation of large branches, and prevents such from being formed, or by planting much wider, and thereby giving the trees every inducement and opportunity to produce an abundance of large horizontal branches. Consequently if wide-spreading ornamental trees are required, wide-planting must be followed, whereas if unbranched clean timber is desired, the planting must be close enough to secure this.

When complete canopy is secured, the number of stomata per acre is about the same in any one kind, whether it be planted closely or widely, and there is consequently about the same amount of carbon fixed, and of timber formed, but with this difference, that if the planting be wide, numerous heavy branches will be formed, themselves useless as timber, and causing knots in the main trunk, which render it also useless for timber purposes, whereas if the planting be too close, the wood formation is performed by too many individual stems, many of which, to prevent suffocation, must be removed while too small to be of use. For economic timber production therefore a happy medium is desirable, which is best obtained by stocking so closely as to produce close canopy in three or four years, and by thereafter thinning often and lightly, removing sufficient on each occasion to prevent crowding, but not enough to admit direct sunlight, or the formation of heavy branches. The original espacement as well as the subsequent thinnings must therefore vary in accordance with kind, and also in accordance with soil, aspect, rainfall, and all other affecting factors, and cannot be definitely settled except upon the merits of each individual case.

Canopy has been spoken of as a cure for the drying effect of direct sunlight by reducing the temperature under the trees, and consequently preventing a certain amount of evaporation from the surface of the soil. It must also be borne in mind that at a high temperature the atmosphere carries an amount of moisture in gaseous form, which at a lower temperature surcharges it, and becomes deposited in the form of mist, dew, or rain. The variation in temperature between the atmosphere outside and that below the covering canopy depends during bright weather on the age, depth and density of that canopy, but is often sufficient when the atmosphere is moisture laden to cause an aqueous deposit inside the forest, while outside there is none, and is usually sufficient to cause a moistness to pervade forest shade, and have considerable influence on tree growth, hence the necessity for keeping the outskirts of a forest or plantation dense, and unpruned to an extent sufficient to exclude hot, drying winds.

The effect of this consequently lowered soil temperature is beneficial not only for the same reasons as the lowered atmospheric temperature under canopy, but also in that it causes the trees to start later in spring, and thereby avoid the danger of late frosts, which are often injurious to deciduous trees grown in the open.

The main factors which influence tree life from the start onward are temperature, rainfall, and soil.

"*Temperature*" affects every kind of plant, but in varying degree, consequently in so far as not affected by other causes, each species has a belt in the Northern and another belt in the Southern hemisphere, suitable for its existence and culture. This belt would naturally be of regular outline, comprising one or more parallels of latitude, but since ocean currents, monsoon winds, altitude above sea level, distance from the sea, and the conformation of surrounding country, all affect its direction, the result is in most cases a very irregularly waved line, sometimes awanting, occasionally appearing only at certain altitudes, and often containing within itself areas which belong to different isothermal belts; and all other factors being suitable, any tree growing on one part of that belt will succeed if naturalised into another part, in either the Northern or Southern hemisphere, and as far outside the belt as the elasticity of the species will allow.

But in any given area of considerable extent increasing elevation above sea level frequently places several isothermal belts one above another, since increasing elevation has the same effect on temperature as higher latitude, as for instance at Kilimanjaro, where all the successive isothermal zones from the tropics at the base to to the snow line at the top may be passed through.

Both altitude and latitude are affected by many outside factors, but in a general way one degree of latitude has about the same effect on the mean temperature as 500 ft. altitude, viz. 1·5° Fahr.

The effect produced by actual altitude is however modified very much by comparative altitude; thus one place at an elevation of 3,000 feet placed above most of the surrounding country may have a temperature varying little from the average at any time, and never reaching freezing point, and therefore suitable for many kinds of trees which it is impossible to cultivate at another neighbouring spot at 1,000 ft. altitude falling within the same isothermal line, but affected by extremes of heat and cold as such valleys usually are.

"*Rainfall.*" The kinds of trees composing any natural bush are usually found to be arranged in accordance with the amount of moisture which these trees can exhale; that again is dependent on the amount of moisture available (the kinds which require more than is available gradually dying out), so that except where there are perpetual subterranean supplies of water, the character of the natural arboreal vegetation is regulated by rainfall, and in sylviculture the same survival of the fittest takes place, except sufficient care be exercised when planting to use only kinds befitting the rainfall and the soil.

But the actual rainfall as measured hardly indicates every possibility in sylviculture, in so far as an annual rainfall of say 30 inches of thunder showers in a dry district is not equal to 30 inches of steady coast rain in another moister one.

Almost everywhere within reasonable elevation and latitude, and where man has not interfered, a high regular rainfall is accompanied by a natural arborescent vegetation, or is capable of producing an artificial forest, while with a very low rainfall, tree vegetation is naturally absent, or so modified in character as to be comparatively useless, and any attempt to carry on sylvicultural operations in such a region requires care and experience.

That a high regular rainfall assists woodland growth is certain; it is also claimed that forest growth tends to increase the humidity in the manner already explained, and thereby produce conditions more suitable for extended sylviculture.

"*Soil and Subsoil*" are most important factors in tree growth. Trees require fewer food elements, and some of them in lesser quantity than other agricultural crops, hence their frequent presence on soil which is unfit for cultivation, and hence also the common practice in Europe of planting trees on soil which it is found unprofitable to cultivate; but it by no means follows that because trees will thus exist they should not be allowed to compete with cereals and other crops, on alluvial soils of greater depth, and more highly charged with fertile organic matter.

Frequently even the decomposing rock strata contain these valuable ingredients where they are in the form of soft shale, sandstone, or limestone, and have at some previous period themselves been in the form of alluvial deposit before petrifaction took place. A very large portion of the surface of South Africa has subsoil of this nature, viz.:—stratified rock which on decomposition yields a fairly fertile soil, well suited where deep enough, and where the under-lying rock is soft and natural, for the growth of several kinds of trees, indeed for pines few better soils exist. But South Africa has also at some time been subjected to an enormous amount of subterranean heat and volcanic action, with the result that in many places the stratified rocks over, or under, or in proximity to the then molten matter, have been heated and altered in nature to such an extent as to be impervious to water, impenetrable to tree roots, and very little liable to atmospheric erosion. Where this is the case the impervious subsoil causes saturation during wet times, and is unable to yield sufficient moisture during dry times, and is therefore to be avoided in selecting ground for tree-planting.

Except there be any deleterious constituent present, most trees will thrive on any ordinary soil if given all other suitable conditions, and the selective power of the rootlets already referred to enables most kinds to take what they want from the soil, and reject the rest, though there are well known cases in which a certain kind fails to thrive unless lime or iron be present, and others in which a certain species fails to thrive unless one or other of these be absent.

Such exceptions must be carefully noted in practice, but, beyond them, trees are in general very accommodating in the kind of soil required, provided there be enough of it, and that its texture and mechanical condition be right. Any porous and naturally well drained soil over-lying a subsoil equally porous answers much better than one in which either the soil or subsoil is impermeable or too retentive, such as indurated sandstone, or pot clay. Roots follow moisture, and if the moisture be deep-seated in a porous subsoil, the roots will find their way down to it, and manage to endure long droughts, whereas if an impervious layer be near the surface, the roots are all surface roots, surfeited with sap during wet times, but useless as soon as a prolonged drought sets in. Even deep soil may be reduced in value by the presence of deep dongas acting as drains at a depth at which the water should be all stored up. Where artificial irrigation is practised it is often abused by the too frequent application of water which draws the roots to the surface, and leaves them in a helpless condition if at any time the supply of water for irrigation falls short. In all sylvicultural operations on a commercial scale, it is safer to do without irrigation even though a certain number of trees be thereby lost, since the balance are rendered better able to endure further drought.

The extreme drought of winter and the uncertainty of when rain will begin renders the European practice of winter planting with open roots impracticable here. It is found better to have the ground prepared by ploughing and cross-ploughing during the previous season so as to secure a completely rotted turf, and to delay planting until summer rains have actually commenced. This applies to all kinds except deciduous trees, which must be planted during winter even though artificial watering has to be practised. Single trees can of course be easily planted in spring, and kept watered until rain arrives, but for extensive sylvicultural operations this is impracticable, and it is also unnecessary, since the condition of rest produced by winter in Europe can be produced here at any season by cultural operations, while some of the kinds used here may be successfully transplanted at any season without being in a resting condition. To secure this, however, the young trees must be growing in such a manner that they can be transplanted with a good ball of soil undisturbed at the roots, which is most easily obtained by growing the trees in what are known as transplant tins, say 5 inches deep, and with 20 to 30 trees in each tin. If not too old these trees can be cut out with a trowel or knife, and planted out without any roots or soil being disturbed. Almost all the evergreen kinds usually grown are amenable to this treatment, and if not too large (say 6 inches) seldom suffer at all from transplanting, even though in active growth, but are better to be hardened more or less by receiving reduced water supply for several weeks previous to planting out.

Some kinds, more particularly pines and cypresses, though quite successful under the above treatment may also be grown, and grown much more cheaply, without tins by sowing in open nursery beds, and then by being frequently transplanted while quite young. The effect of this transplanting is to make the plant less dependent on the tap root (which may with advantage be shortened back) and more dependent on the lateral roots which are then produced in greater abundance, until at the final planting each root has a mass of active young lateral roots, and no heavy tap root. As the success of the operation depends on the plant having been frequently deprived of its larger feeding roots and thereby brought into a hard sturdy condition, and simply kept alive, but not kept growing, by the mass of young rootlets, it follows that the more frequently this operation is practised, the more successful are the results. It will also be seen that under this method a strong vigorous plant in growthy condition has small chance of success as compared to a smaller and more hardened plant. The transplanting does not, however, require to be a complete change of site on every occasion, the same purpose being answered after the first transplanting if the plants are lifted *en masse* with a fork, far enough to break any long roots, and then allowed to settle down again where they were. This process is spoken of in the trade as "teasing" the plants, and in experienced hands produces an enormous saving of cost without lessening the results.

A further saving of cost may be made with some kinds by sowing *in situ* where the trees are intended to remain. This is the natural, and theoretically the most perfect method of afforesting, especially for a hot, dry country, since thereby the tap root, which usually finds its way deeper than the lateral roots, is undamaged, and may be able to draw moisture after the surface is very dry. This accounts for the natural forests, and even single trees on the veld, being able to stand more severe drought than most planted trees. Consequently where sowing is practicable it is to be recommnded, and probably its use will be vastly increased in future. But it also has its disadvantages. Many kinds of seed are so fine that they require careful nursery treatment to bring them up, and would be entirely lost if left to themselves in the field. Again, for all kinds, unless the ground be quite clean, there is the danger of seedlings being unable to keep ahead of the weeds during the early stages, or requiring much labour to allow them to do so. There is also the fact that a tree dependent on a deep tap root alone, and without lateral branches, has usually less food supply, and consequently slower growth.

Sowing *in situ* is limited therefore to such kinds as wattles, pines and oaks, which, having large seeds and rapid growth, are able to pull through.

It will be noticed that the removal of the tap root is necessary for trees which have to be transplanted, while its retention is the main desideratum with "in situ" sowings which are to remain permanently where sown.

It will also be noticed that the size of the seed affects sowing, since no kind of seed can be depended on to germinate freely if sown at a greater depth than its own size under the surface.

Thus acorns may be sown an inch deep, while wattles and pines require less than a ¼ inch of covering, and gums require to be sown almost on the surface, and in order to avoid drying out are better to be shaded somewhat.

Whether "in situ" sowings or the use of nursery transplants or seedlings be adopted must depend in each case on which can be done the most economically, *i.e.*, at least cost combined with efficiency, and the further question of whether much or little seed per acre is used must depend on whether the cost of seeding heavy enough to ensure good results is less or greater than the cost of a light seeding together with the filling up labour necessary to give a good crop.

To what extent the cultivation of the soil for and among plantation trees should be carried, depends somewhat on local circumstances. As has been already explained, the practical effect of such tillage is by aeration of the soil to induce surface roots and rapid growth. If these can be always maintained, then the advantage of cultivation is evident, but rapid growth requires large water supply, and where this is likely at times to be wanting, it may be better to give only such cultivation from the start as will secure a slow and hardy growth capable of being maintained through the driest times, and to carefully avoid the most moisture-demanding kinds in such places. The only difficulty then is to secure safety from fire. But since land is comparatively cheap it may be questioned whether, except under exceptional circumstances, it is worth while afforesting such places, so long as suitable and sure ground is obtainable, since the cost of special extra labour on such is sometimes greater than the buying price of good ground on which more satisfactory and more early results are assured.

I have mentioned several methods as less expensive than others, and to be a sound financial investment it is necessary that a low initial cost, as well as a comparatively early return, should be secured, since every additional shilling per acre, as well as every additional year in the rotation, has a telling effect when compound interest on the original outlay goes on for say 50 or 100 years.

It is also necessary on this account to use only kinds which will give a comparatively early return unless the slower kinds have a very much greater value when mature.

Another point is to have the crop suitable for the market whatever that is, or may be expected to be by the time the crop becomes mature, more particularly if the expected market be a purely local one. The pecuniary returns must form the central point in all calculations connected with sylvicultural work, with the exception of the few cases, such as drift sand reclamation, in which the purpose served is more important than the returns.

It has been noted that each kind of tree, as well as each class of trees, has its individual characteristics and requirements which must be carefully studied. Thus pines as a class yielding much humus, and requiring comparatively little moisture, are particularly adapted for use on hill slopes where few other kinds would survive.

Gums and wattles on the contrary yield little humus, and have heavy moisture requirements, and consequently are better adapted for moist alluvial valleys such as alone suit oaks, the choice between these three kinds depending on whether an early return of mining timber, or bark and firewood, will pay better than a later return of more valuable oak timber.

Though natives of hot and dry Australian regions, and having very different requirements among themselves, the gums as a class must be considered harder on the soil than most other kinds, yielding little of the nature of foliage refuse, and making more demands for moisture than their canopy and shade induce, so they require a good deal of subterranean moisture, and probably do not improve a dry soil to anything like the same extent as pines do.

Then again some trees can endure a great deal of cover over them, as for example almost all our indigenous trees, or say pinus halepensis, while others like *Pinus pinaster* do well as a pure, equal-aged, and equal-sized forest of that one kind, but die out when mixed with other kinds, which overtop and suppress them.

These individual characteristics are too numerous for mention here, and affect more the practice than the principles of sylviculture, as also does much of what has had to be introduced into this paper to make it clear. But in order to make sylviculture successful these individual characteristics, as well as all the principles affecting the subject, require to be taken into consideration together, and from them a working plan of the proposed work fully arranged, which should not afterwards be lightly departed from.

I will therefore close by briefly recapitulating the more important principles, and mentioning such others as have not already been alluded to.

"*Natural factors of tree growth.*"—Trees like all other organic beings are more or less subject to the action of external influences, which have produced, by gradual evolution, special forms particularly adapted for special conditions. In every case the suitability of the kind to the locality and conditions must be studied before planting.

Temperature places limits on each kind, beyond which it is not successful.

Where there is no underground supply of moisture, drought weeds out such kinds as have requirements in excess of the local annual rainfall.

Trees draw upon the soil and atmosphere for their food. They are more or less affected by the chemical composition of the soil (especially some kinds of trees), but many kinds have, and exercise, much selective power in their feeding, so that the depth and texture of the soil and the nature of the subsoil are in most cases of more importance than the chemical composition.

Impervious subsoil causes surface roots which are unable to maintain growth, or even life, during prolonged drought.

Mountain slopes secure drainage, and South East slopes usually secure more rainfall than other aspects, and being away from the drying effect of the sun, keep it better.

"*Sylvicultural factors of tree growth.*"—Deciduous trees must be planted when leafless. Other kinds must either be planted with undisturbed root-balls, or have been previously forced into a dormant condition by cultural treatment.

Trees (especially some kinds) improve and accumulate soil, and leave it in condition at the end of a rotation for kinds which at the commencement of the rotation it was unsuited for.

By canopy trees reduce the temperature, and thereby cause a moist atmosphere to deposit moisture, which without the forestal influence is retained in the warmer atmosphere.

Canopy prevents evaporation, and when unpruned and unbroken at the margins prevents the ingress of drying winds.

Cultivation assists rapid growth, and is an advantage at the start, where such growth can afterwards be maintained. Otherwise its value varies with local circumstances.

Irrigation is always subject to abuse, and abundant water supply is usually to be avoided unless it can be maintained throughout, as any temporary check is then more injurious than if growth had been slow and steady.

Pure forest is much preferable to mixed forest in the present condition of our knowledge of this subject.

Light-demanding kinds must have pure forest except they be far ahead of underplanted shade bearers, while shade bearers are usually better of cover at first.

Espacement should be close enough to always secure canopy without crowding, and pruning or thinning must be practised whenever necessary.

Trees with heavy branches are useless for technical purposes, and the production of these must be prevented either by close planting or by pruning.

"*Economic factors in Sylviculture.*"—Including purchase price of land high-priced good soil easily worked is more profitable than low-priced soil, bad, or difficult to work.

"In situ" sowings of the larger seeded kinds are the natural, drought resisting, and economic method of afforesting where ground is clean and sufficiently moist. Small seeded kinds require nursery treatment.

Next to sowings "teased" seedlings are to be recommended in experienced hands, and transpants to other planters. In each case trees 6 inches high are preferred to larger for extensive planting, except with regard to deciduous trees.

Where natural regeneration by seed is practicable, as under felled wattles, matured pines, &c., that is the most economic method, and requires only protection against fire.

All sylvicultural labour is lost which does not receive efficient protection from damage by fire and trespass. Against fire a clean belt under non-inflammable trees is most effective.

For convenient working large plantations should have roads left not more than 200 yards apart. These if kept thoroughly clean act also as fire protections.

Except on an experimental scale, only the few kinds of proved value and well recognised qualities should be used.

A small area well stocked is more productive of good material than a large area badly stocked, and to be thoroughly successful all filling up should be done during the first year.

Kinds used must suit the market, and except the market be quite local, plantations should be near the railway.

Economic maturity depends on many outside factors and may range from two years old for hut-wattles to 20, 50, 100, or more years for heavy timber.

To yield a steady annual return, haphazard planting of job lots is thoroughly unsuccessful. The first preliminary is a carefully studied out working plan which must afterwards be rigidly adhered to, unless very special circumstances interfere. This applies to small as well as to large plantations.

So far as successful results will allow heavy initial expenditure is to be avoided, since compound interest on this gives a plantation an enormous cost in a long rotation.

Now—Since the natural forests of the Colony are composed of hardwoods, and the import of timber is very largely pine timber, pine production must be enormously increased, and I need only mention that except in the proximity of mines or towns where there are other special demands, those who would profit by sylviculture would do well to make pines their mainstay, and in the preparation and culture of their trees and land, to rely more on sound common sense in the application of the principles above mentioned than on any formula of so-called necessary routine, which may or may not be successful in accordance with the special circumstances of each case.